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(54) A universal battery charging system and method.

(57) The invention relates to a battery charging system for charging a battery (54). The system includes means (56,58,62) for determining the state of charge of the battery (54) during charging, means (38,42) for supplying current to the battery (54), means (30) for controlling the current supply means (38,42). Said control means (30) are responsive to the state of charge determining means (56,58,62) at plural times during charging and controlling said supplying means (38,42) to follow a charging schedule responsive to current supplied to the battery (54), voltage of the battery (54) and time.

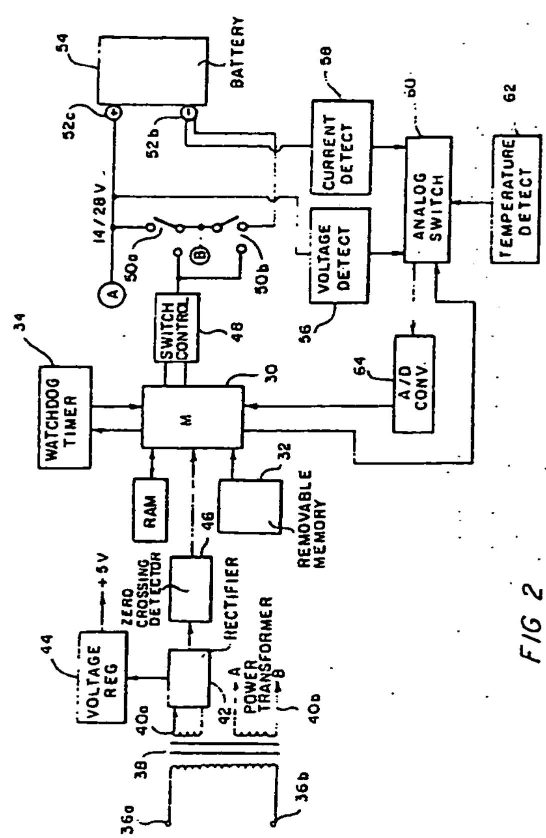

FIG 2

EP 0 293 664 A2

A Universal Battery Charging System and Method

Background of the Invention

This invention relates to devices for charging or recharging electric batteries and particularly a universal battery recharger for batteries having different charging characteristics.

Electric batteries are utilized to provide mobility to a great number of devices powered by electric motors or which otherwise utilize electricity. In some such devices, such as automobiles, the device provides a recharging circuit to the battery so that the battery is kept at a full level of charge as long as the recharging circuit is operative. However, it is a frequent occurence that components of the device, such as the headlights on an automobile, are inadvertently left powered and when the charging circuit is not resupplying charging voltage. Consequently, the battery drains off most of its energy until it is recharged by an external circuit. Many other devices, such as golf carts, forklift vehicles, and numerous other portable devices are designed to draw their power from the battery without replacing the power by a charging circuit during the operation of the device. Typically, in such devices, the device is operated for a period of time and when the device is not in operation the battery is connected to an external source of power, such as a battery charger to recharge the battery. Consequently, there is a considerable need for battery charging devices to recharge batteries which either through design or inadvertance have become discharged.

It is known to provide battery charges which apply a potential voltage having a direct current across the battery terminals for a period of time. The cells of the battery absorb and store a portion of the energy provided thereby. Different types of batteries have different charging characteristics. Accordingly, a charging circuit which is designed for a particular type of battery may not function efficiently or at all as a recharger for a different type of battery or even for the same type of battery manufactured by different manufacturers. Accordingly, it is known to develop a discreet circuit which provides a charging current to a battery in a charging profile which matches the battery specification.

A battery charging profile characteristic preferably includes three or mor phas s during which varying amounts of current and/or voltage are supplied to the battery. One typical recharging sequence comprises a first phase in which a constant current is provided to the battery terminals until the battery voltage is brought up to the full rated level. Once th voltage has been brought up to l vel, a constant voltage or current may be provided to the battery for a period of time which is often related to the period of time which elapsed during the first phase, for example, a period of time equal to twice the period of time taken to bring the voltage up to its rated level. Upon the completion of the second phase, a small current is applied across the battery terminals to maintain the charge at its maximum, this third phase is sometimes called a "trickle" charging phase.

The precise time, voltage, and current which should optimally be applied to a particular battery type to recharge it often varies from one battery to another. However, many battery users do not wish to operate plural battery rechargers, one for each type of battery and operate a battery charger having a "typical" or "average" charging characteristic. However, such an "average" battery charger may not meet the desired charging characteristics of any of the batteries on which it is utilized.

Accordingly, it is an object of the present invention to provide a battery charging method and apparatus which can efficiently recharge many different types of batteries.

It is a further object of the present invention to provide a battery charging method and apparatus in which different types of batteries may be recharged without the necessity of changing the components of the charger except for a charging characteristic memory.

It is yet a further object of the present invention to provide a battery charging method and apparatus for charging batteries having both low sulfation and high sulfation characteristics.

It is yet another object of the present invention to provide a novel battery charging method and apparatus which will charge batteries having charging characteristics which are currently unknown or unanticipated.

The invention will now be described in more detail by way of example with reference to the accompanying drawings in which:

DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial representation of a battery charging system embodying the present invention;

Figure 2 is a block diagram of a battery charging system embodying the present invention;

Figure 3 is a circuit diagram of a micro-processor control circuit for the battery charger of Figure 3;

Figures 4-7 are logic flow charts for a battery charging system operating in accordance with various embodiments of the present inv ntion.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to Figure 1, a battery charging system of the present invention may be housed in a housing ten which protects the circuit from external elements such as water and dirt and which ensures that foreign objects, including the hands of the user, are not allowed in proximity of any high voltages which may be present within the battery charger circuit. A carrying strap 12 may be carried at the top of the housing ten to facilitate transportation of the battery charger circuit. Electrical power may be provided to the battery charger system by a conventional electric plug 14. A charging voltage provided by the battery charger may be provided to a battery by means of electrical cables which terminate in spring loaded clamps 16a, 16b for connection to the terminals of a battery to be charged.

Appropriate vents 18 may be provided at various locations along the housing ten to provide ambiant air cooling of the printed circuit boards within the battery charger.

The front of the battery charger may include various indicating devices such as lamps 20a, 20b, and 20c which are controlled by the circuitry of the battery charger to indicate to the user the current charging condition of the battery charger. Additionally, an ammeter 22 and a voltmeter (not shown) may be provided to the user the current amount of amperage and voltage being supplied to the battery. The operation of the battery charger may be ultimately controlled by an on/off switch 24.

In operation, the battery charger is brought into physical proximity of a battery to be charged. The battery charger is powered by plugging the electrical plug 14 into an available socket supplying the appropriate electrical current, generally an alternating current of either 110 volt or 220 volt magnitude. The clamps 16a, 16b are coded to indicate which clamp is associated with the negative terminal and the clamps are placed on the terminals of the battery in accordance with their indicated polarity. The battery charger may then be started by operation of the switch 24 at which point the automatic circuits of the battery charger, explained b low, provide the appropriate amounts of current and/or voltag to the battery to be recharged.

In a battery charger of the present invention, an access slate (not shown) may be provided at an appropriate location on the housing ten to facilitate the replacement of a charger characteristic memory, so that the charge may be readily configured to recharge different types of batteries.

With reference to Figure 2, a battery charger of the present invention may be controlled by a micro-processor 30 may include elements of read only or random access memory as desired and is well known. Additionally, the micro-processor 30 may communicate with a removable memory 32 which contains signals indicative of the charging characteristics of one or more types of batteries. The micro-processor may be further in communication with a watchdog timer circuit 34.

Power may be supplied to the battery charger circuit from a conventional alternating source to power input terminals 36a, 36b. Power obtained across the power input terminals 36a, 36b may be provided to a transformer 38 which has plural secondary windings 40a, 40b, each secondary winding obtaining a predetermined proportion of the voltage provided across the power input terminals 36a, 36b. Power to be provided to the logic circuits of the battery charger printed circuit board may be rectified through a rectifier 42 and regulated by a conventional voltage regulator 44. The electrical power rectified in rectifier 42 may also be provided to a zero crossing detector 46 which is in communication with the micro-processor 30.

The micro-processor is programmed to provide reset signals at certain predetermined minimum periods of time to the watch dog timer circuit 34. If the micro-processor 34 fails to provide such resetting signals within the predetermined period of time, the watch dog timer 34 may sound an alarm and/or reset the micro-processor 30. In this way, sanity of the operation of the micro-processor 30 is insured and the battery 54 being recharged is not overcharged.

The removable memory 32 contains logic tables and switch settings which instruct the micro-processor 30 on the charging characteristics of one or more types of batteries. By the use of a modular and tabular control method, the micro-processor 30 may contain a generalized series of instructions to implement its control functions in accordance with the specific tables/settings provided in the removable memory 32. In this way a simple removable memory 32 may control the entire battery charger circuit and provide for a series of recharging phases which is precisely tuned to the needs of batteries being recharged.

Control of the charging of the battery is obtained through the switch control 48 and the micro-processor 30. Because the micro-processor 30 knows the phase of the power being provided to

the battery through the switch 50b, the micro-processor 30 operates the switch control circuit 48 to operate the switches 50a and 50b in a desired manner in accordance with the phase of the power signal being supplied to the battery 54. For example, if full power is desired to be applied to the battery 54, the switches 50a and 50b could be continually closed. If, on the other hand, only a small amount of power were desired to be provided to the battery 54, the switches 50a, 50b could be opened at those phases of the power signal in which the voltage is high and closed (i.e., providing power to the battery) only when the voltage is low.

In comparison with other schemes of controlling the power to the battery to be charged, the present invention controls the switching of the power to the battery directly, and, thus, is able to vary the amount of power provided to the battery without the need for additional circuitry or a wide range of conditions.

The voltage detect circuit 56, the current detect circuit 58 and the temperature detect circuit 52 determine the characteristics of the recharging performance which are supplied to an analog switch 60. The analog switch 60 is controlled by the micro-processor 30 and provides the analog signal received from either the voltage, current or temperature detect circuits to the output terminal of the analog switch 60. The signal contained in output terminal of the analog switch 60 is available to the analog to digital converter 64 which in turn is supplied to the micro-processor 30. Thus, the micro-processor 30 is able to change the charging characteristics supplied to the battery in accordance with detected voltage, detected current, temperature, time, history of any of the foregoing parameters, and all combinations thereof.

With reference to Figure 3, a battery charging circuit of the present invention may include a micro-processor 70. One of the outputs of the micro-processor 70 may be tied through a capacitor 72 to a CMOS dual retriggering monostable 74 which communicates with a second CMOS dual retriggering monostable 76 and with the $\overline{\text{reset}}$ lead of the micro-processor 70 through a drive transistor 76 and driver resister 78.

In operation, the micro-processor is programmed to provide a transitory signal on the output tied to the capacitor 72 on a regularly recurring basis. As long as the micro-processor is cycling correctly, the transitory signal is applied to the capacitor 72 and the first retriggering monostable provides a signal to the $\overline{\text{reset}}$ pin of the micro-processor to indicate that a reset is not need d. If the transitory signal is not received at the capacitor 72 from the micro-processor 70, the first retriggering monostable no longer holds the $\overline{\text{res t}}$ signal and the micro-processor 70 is reset to begin processing from the start. In this manner, the recharger circuit board is assured that the micro-processor 70 is properly cycling through its coding. The second retriggering monostable 76 is connected to the first monostable 74 so that the watch dog timer circuit can be powered up without continuing to reset the micro-processor 70.

The micro-processor 70 is electrically connected through two output ports 80 and 82 to transistors 84a, 84b. Transistors 84a, 84b drive an SCR gate which completes an electrical circuit to the positive and negative terminals 88a, 88b of the battery to be recharged.

In operation, when the output ports 80, 82 are energized the SCR drive gate is enabled and a recharging current is provided to the terminals of the battery 88a, 88b. Two ports are used to prevent the inadvertent application of the charging voltage to the battery terminals 88a, 88b as both ports have to be in the required states in order for the SCR drive gate to be energized.

Power to the battery charging circuit may be provided by standard household alternating current, typically 110 volts or 120 volts in the United States or 220/240 volts in other countries. The alternating current is supplied to the power input terminals 90a, 90b, applied across a transformer 92 and induced upon secondary windings 94. The current received at the secondary windings is applied to a rectifier bridge 96. The output of the rectifier bridge 96 is applied to a voltage divider consisting of two resistors 98a, 98b. The divided voltage is provided to one terminal of a comparator 100. The other terminal of the comparator 100 is connected to a low voltage of approximately the same voltage as the divided voltage. The output of the comparator 100 is connected through a diode 102 to the interrupt lead of the micro-processor 70. Thus, the micro-processor 70 is informed of the zero crossing of the power received at the input terminals 90a, 90b and available for application to the battery terminals 88a, 88b. The rectified voltage may be provided to a conventional voltage regulator 104 to provide a logic voltage to power the various logic boards on the battery charging circuit.

The precise time, voltage, and current which should optimumly be applied to a particular battery type to recharge it often varies from one battery type to another. However, many battery users do not wish to operate plural battery rechargers, one for each type of battery and operate a battery charger having a "typical" charging characteristics. However, such a battery charger may not meet the desired the charging characteristics of any of the batteries on which it is utiliz d.

An amperage detection circuit measures amperage being supplied to the battery connected at the battery terminals 88a, 88b, by connecting one

terminal of an op amp 114 to the negative terminal of the battery 88b and connecting the other terminal of the op amp 114 in a feedback loop which includes a calibrating resistor 116 for establishing the calibration point of the amperage detection circuit. The output of th op amp 114 is connected through a resistor 118 to one of the input terminals of an analog switch 120. Another of the input terminals of the analog switch 120 is connected to a thermistor for measurement of the ambiant temperature of the battery charger.

A voltage detection circuit may supply a measure of the voltage across the battery. For example, in the 24 volt system, the voltage can be divided by voltage divider network comprising of two resistors 124a, 124b. The base of a transistor 126 is being driven by the divided voltage. The output of the transistor 126 may be provided to the analog switch 120 after being calibrated by a calibrating resistor 128. The output of the analog switch 120 may be provided to an A-to-D converter 130 which is controlled by the micro-processor 70 through A-D ports 132a, 132b, 132c. The first A-D port 132a may be used to provide a clock from the micro-processor 70 to the A-D converter 130. The second port 132b may be utilized to provide a signal indicating a reset condition to the A-D converter 130. The third A-D port may be utilized to provide the output of the A-D converter 130 to the micro-processor 70.

The value which is provided to the A-D converter 130 by the analog switch 120 may be controlled by select leads 136a, 136b, 136c, 136d which communicate between the micro-processor 70 and the analog switch 120. The select leads are used to trigger the analog switch to provide the value of a specified input at the output terminal. The value is received from the thermistor, from the amperage detection circuit, from the voltage detection circuit upper range, or from the voltage detection circuit lower range.

The entire control of the micro-processor 70 may be effected through a removable memory 140 which can provide signals customizing the recharging circuit to the charging characteristics of any particular battery type. Because the memory 140 is removable, the circuit may be made to charge varying types of batteries by merely changing the memory element.

In operation, the battery charger circuit and in particular the micro-processor 70 can control the phase of the firing of the SCR gate drive 86 in correspondence with the phase of the recharging power made available to the recharging circuit. Because the micro-processor 70 is interrupted when the zero crossing of the recharging power is detected, the micro-processor 70 may control the phase of the firing of the SCR drive gate 86 to correspond to the proportion of the input power desired to be applied to the battery terminals 88a, 88b.

Status indicating 134a, 134b, 134c, 134d may be controlled by the micro-processor 70 to indicate the status of th recharging operation.

With reference to Figure 4, the micro-processor and its associated removable memory may be provided with a series of signals which implement a particular logic sequence related to the charging characteristic for each type of battery. A logic sequence which has been found to be particularly beneficial for lead-calcium batteries, is shown in the flow chart of Figure 4. In this logic sequence, at the start of the sequence, a one second delay is used to prevent arcing on the battery connection. Once the logic has established that the battery is connected, the micro-processor 70 can perform a deep discharge check in which the charger gradually increases the battery current to 2.5 amps over a period of ten seconds. If the battery will not draw 2.5 amps at the expiration of ten seconds, the battery is considered to be in deep discharge (high impedence) and the charger continues to apply voltage until the battery draws more than 2.5 amps.

If the battery draws 2.5 amps prior to the expiration of the ten second period, the voltage level of the battery is checked and if less than four volts the battery is treated as a deep discharge, (low impedence) and is charged at a rate of 2.5 amps until the voltage exceeds four volts.

If upon initial connection the battery draws greater than 2.5 amps within ten seconds and at a voltage greater than four volts, the charger proceeds immediately to the constant current mode. In the constant current mode the battery is charged at a mean current of five amps for a period of one hour at which point the voltage is measured and if greater than 13.5 volts the charge is continued at five amps and otherwise continued at ten amps mean (15 amps RMS). In either case, the charge is continued at the indicated rate until the voltage exceeds 16 volts or until the passage of 24 hours. After a period of 24 hours passes, the charger goes into a float mode sequence in which the battery is held at 13.8 volts with a current limit of ten amps until the charger is switched off or battery is disconnected. If the voltage measurements achieves 16 volts for a period of time equal to time of the charge plus four hours in a constant voltage mode.

On the expiration of the constant voltage mode, the battery is held in the float mode until the charger is switched off or the battery is disconnected.

With reference to Figure 5, the battery charger circuit may also follow any other logic sequence to achieve a desired charging characteristic. the logic sequence indicated in the flow chart of Figure 5

has been found to be particularly advantageous for nickel/zinc batteries. In this logic sequence, the micro- processor delays one second to prevent arcing on battery connection and may wait until a signal is obtained indicating that the battery is connected to the charging circuit. Once the battery is connected, the battery may be charged at ten amps (mean) until the battery voltage increases to 13.5 volts. When the battery voltage exceeds 13.5 volts, the charging circuit may enter a constant voltage phase in which the battery is held at 13.5 volts for a period of time equal to 30 minutes plus the amount of time taken during the constant current phase. The constant voltage phase is limited to a total of 18 hours after the battery has been connected to the supply.

Upon completion of the constant voltage phase, the charger executes a float mode in which the battery is held at 13.5 volts with a limit of 10 amps of current. The battery is held in the float until the battery charger is switched off or the battery is disconnected.

With reference to Figure 6, a logic sequence is presented in the flow chart which has been found particularly advantageous for sealed lead-calcium batteries and similar closed cell batteries. In the logic sequence, the battery charger may delay one second and insure that the battery is connected before energizing the recharging circuitry. The charging current may be increased gradually to five amps within that period, maximum voltage is applied to the battery terminals until five amps is achieved at which point the charging cycle enters the constant current mode.

With continued reference to Figure 6, if the battery draws five amps upon initial testing, then the battery may be checked to determine whether the voltage is greater than four volts. If the voltage exceeds four volts the battery charging circuit can enter the constant current mode, described below. Otherwise, the battery is charged at ten amps for one hour and if not yet reaching 13.5 volts then the battery is then charged at 20 amps until 13.5 volts is achieved.

In the constant current mode, the battery is charged at a voltage V_1 for a period of time equal to two hours plus one-half the previous charge time with a maximum of 18 hours between initial battery connection and the end of the constant current mode. Once the battery charge circuit exits the constant current mode, it enters a float mode in which the battery is held at 13.8 volts with a maximum of ten amps. The battery charging circuit remains in this float mode until switched off or until the battery disconnects.

Finally, a specific aparatus has been described for performing the method of this invention. A great many obvious variations of this apparatus will be readily apparent which corresponds generally to the alternative methods described. The invention is claimed in the following claims which are to be accorded a full range of equivalents.

Claims

1. A battery charger, characterized by a source of alternating current; a microprocessor (30); a watchdog timer circuit (34) to reset said microprocessor (30) upon the failure of said microprocessor (30) to provide a predetermined signal within a predetermined interval of time; a zero crossing detector (46) for providing a signal to said microprocessor (30) whenever the voltage of said alternating current is approximately zero; power distribution means (38, 42) controlled by said microprocessor (30) to supply a desired proportion of said alternating current to the terminals (52b, 52c) of a battery (54) being charged said power distribution means (38, 42) including an interlock signal to prevent the supply of said current to the terminals (52b, 52c) until specified by said microprocessor (30); battery connection sensing means (106) to provide to said microprocessor (30) a signal indicative of the attachment of the terminals (52b, 52c) of the battery (54) to the battery charger (10); a current sensing circuit (58) to provide an analog signal responsively to the amount of alternating current being provided to the terminals (52b, 52c) of the battery (54); a voltage sensing circuit (56) to provide an analog signal responsively to the amount of voltage potential across the terminals (52b, 52c) of the battery (54); a temperature sensing circuit (62) to provide an analog signal responsively to a temperature; analog switch means (60) having plural input terminals, operatively connected to the analog signals provided by the current sensing circuit (58), voltage sensing circuit (56) and temperature sensing circuit (62) and being controlled by said microprocessor (30) to provide an output analog signal responsively to the analog signal appearing at a selected one of the input terminals; and an analog to digital converter (64) operatively connected to the output analog signal of the analog switch means (60) and providing to the microprocessor (30) a digital signal responsively to the output analog signal.

2. The battery charger of claim 1, characterized in that said desired portion of said alternating current is provided to the battery terminals (52b, 52c) by a switch means (50a, 50b) operated by said microprocessor (30).

3. The battery charger of claim 2, characterized in that said switch means (50a, 50b) are operated by said microprocessor (30) in timed relation to the signal provided by said z ro crossing detector (46).

4. The batt ry charger of any one of the preceding claims, characterized by readily removable memory means (32) operatively connected to said microprocessor (30) to provide signals indicative of the desired charge characteristics of the type of battery (54) being charged.

5. In a battery charger comprising a microprocessor (30), power distribution circuit (38, 42) controlled by said microprocessor (30), and plural removable microprocessor memories (32), each memory (32) containing signals representing the charging characteristics of one or more types of batteries (54), a method of charging plural batteries (54) of at least two different types, being characterized by:

(a) electrically connecting the battery charger (10) in turn to each of the batteries (54) to be charged;

(b) electrically connecting to the microprocessor (30) in turn the one of the removable memories (32) which contains the signals representing the charging characteristics of the type of the connected battery (54);

(c) charging in turn the connected battery (54) under the control of said microprocessor (30).

6. A battery charging system, characterized by: a battery (54); means (56, 58, 62) for determining the state of charge of the battery (54) during charging; means (38, 42) for supplying current to the battery (54); means (30) for controlling the current supply means (38, 42), said control means (30) being responsive to the state of charge determining means (56, 58, 62) at plural times during charging and controlling said supplying means (38, 42) to follow a charging schedule responsive to current supplied to the battery (54), voltage of the battery (54) and time.

7. The battery charging system of claim 6, characterized in that a portion (40a, 40b) of said control means (38, 42) is readily replaceable with another similar portion (40a, 40b) of said control means (38, 42) to follow a second charging schedule so that different types of batteries (54) may be recharged by merely replacing said portion (40a, 40b).

8. A battery charging system, characterized by: a battery (54); means (38, 42) for supplying current to the battery (54); means (58) for determining the current being supplied to the battery; means (56) for determining the voltage across the battery; and means (30) for controlling the current supply means (38, 42), said control means (30) being responsive to said current determining means (58) and to said voltage determining means (56).

9. In a battery charging syst m comprising a battery (54) having a maximum voltage and a means (38, 42) for supplying current to the battery (54), a method of charging a battery (54), being characterized by the steps of:
electrically connecting said battery (56) to said current supply means (38, 42); gradually increasing the current supplied to the battery (54) to a predetermined current check point or until a predetermined time point whichever occurs earlier;
measuring the voltage across the battery (54) when the current is at said current check point to provide a voltage test reading; operating said current supply means (38, 42) responsively to said voltage test reading.

10. The method of claim 9, characterized in that said step of operating said current supply means (38, 42) comprises applying Voltage V_T to the battery (54) until the battery current reaches said predetermined current check point unless said predetermined time point occurs earlier.

11. The method of claim 9, characterized in that said steps of operating said current supply means (38, 42) comprises applying a first predetermined constant current to the battery (54) until the voltage test reading exceeds a predetermined voltage check point.

12. The method of claims 10 or 11, characterized in that said step of operating said current supply means (38, 42) further comprises the steps of:
applying a second predetermined constant current for a first period of time; measuring the voltage across the battery (54) to provide a second voltage test reading; if the second voltage test reading is less than or equal to the first predetermined level, applying a third predetermined constant current until the voltage reaches said second predetermined level.

13. The method of claim 12,characterized in that said step of operating said current supply means (38, 42) further comprises:
applying a constant voltage at a third predetermined level for a duration of time related to the duration of time utilized to charge the battery (54) to said third predetermined level.

14. A method of determining the degree of sulfation of a battery, characterized by the steps of:

(a) supplying current to the battery (54) in a gradually increasing manner; and

(b) measuring the voltage across the battery (54) at the earlier of the passage of a predetermined duration of time or the attainment of a predetermined level of current.

15. A method of charging relatively recently sulfated batteries, characterized by the steps of:

(a) applying a constant voltage across the terminals (52b, 52c) of a battery (54) as long as a charging current r mains below a first pr determined current level;

(b) varying the voltage supplied to a charging circuit to provide a constant, predetermined, charging current;

(c) measuring the voltage across the battery (54) after a predetermined period of time; and

(d) providing a second predetermined charging current if the measured voltage is less than a predetermined voltage level.

16. A method of charging batteries, characterized by the steps of:

(a) applying a constant predetermined current to the battery (54) until the voltage across the bat tery (54) reaches a first predetermined level;

(b) varying the voltage supplied to a charging circuit to provide a constant, predetermined, charging current;

(c) measuring the voltage across the battery (54) after a predetermined period of time; and

(d) providing a second predetermined charging current if the measured voltage is less than a predetermined voltage level.

17. A battery charging circuit, characterized by: a source of alternating current; a microprocessor (30); a power distribution circuit (38, 42) powered by said alternating current source and controlled by said microprocessor (30) to provide a desired amount of current to a battery (54) to be charged; a phase detection means (30) to determine the phase of the alternating current; and a microprocessor memory means (32) operating said microprocessor (30) so that the desired amount of current is provided with reference to the phase of the alternating current.

18. The battery charger circuit of claim 17, characterized in that said microprocessor memory means (32) is readily replaceable by a similar memory means.

19. A method of charging one of two types of batteries, characterized by the steps of:

(a) measuring the open-circuit voltage of a battery (54) to be charged to determine the battery type;

(b) automatically supplying a first predetermined charging current within a first predetermined charging voltage limit if the battery (54) is a first type; and

(c) automatically supplying a second predetermined charging current within a second predetermined voltage limit if the battery (54) is a second type.

20. The method of claim 5, characterized by the step of electrically connecting to the microprocessor (30) the signals within the one said removable memory (32) related to the charging characteristics of the type of the connected battery (54).

21. A battery charge circuit, characterized by a micro-processor (30) which is responsive to the phase of a current being supplied to a battery (54) being charged to provide a desired proportion of the current to said battery (54) and which varies the desired proportion relative to the charged state of the battery (54).

22. The circuit of claim 21, characterized in that the micro-processor (30) is interrupted by signals related to the phase of the current.

23. The circuit of claim 21 or 22, characterized in that the micro-processor (30) varies the desired proportion with reference to the voltage and current of the charging current.

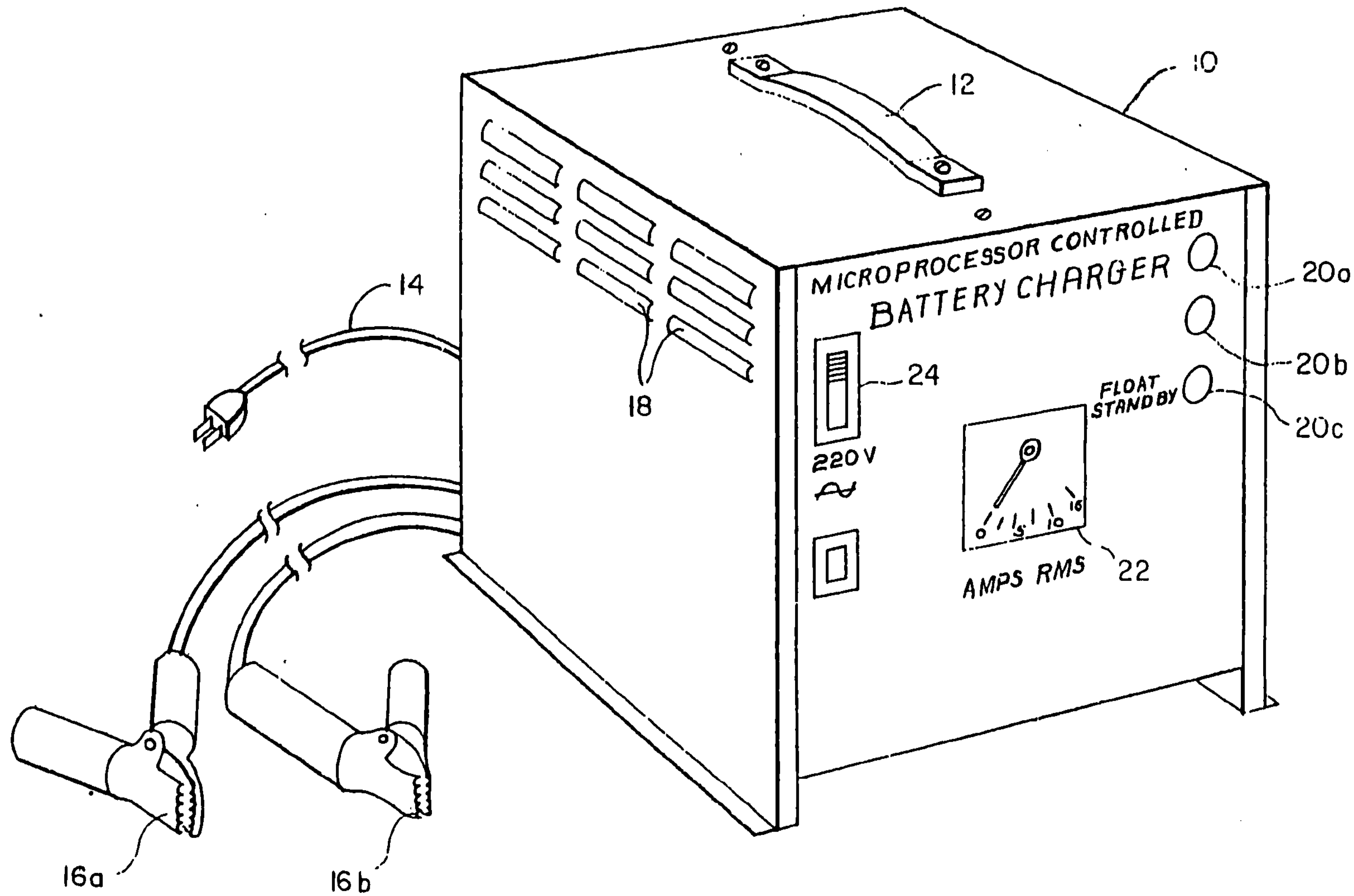
MICROPROCESSOR CONTROLLED
BATTERY CHARGER
220V
FLOAT
STAND BY
AMPS RMS
0
5
10
15
10
12
14
16a
16b
18
20a
20b
20c
22
24

FIG. 1

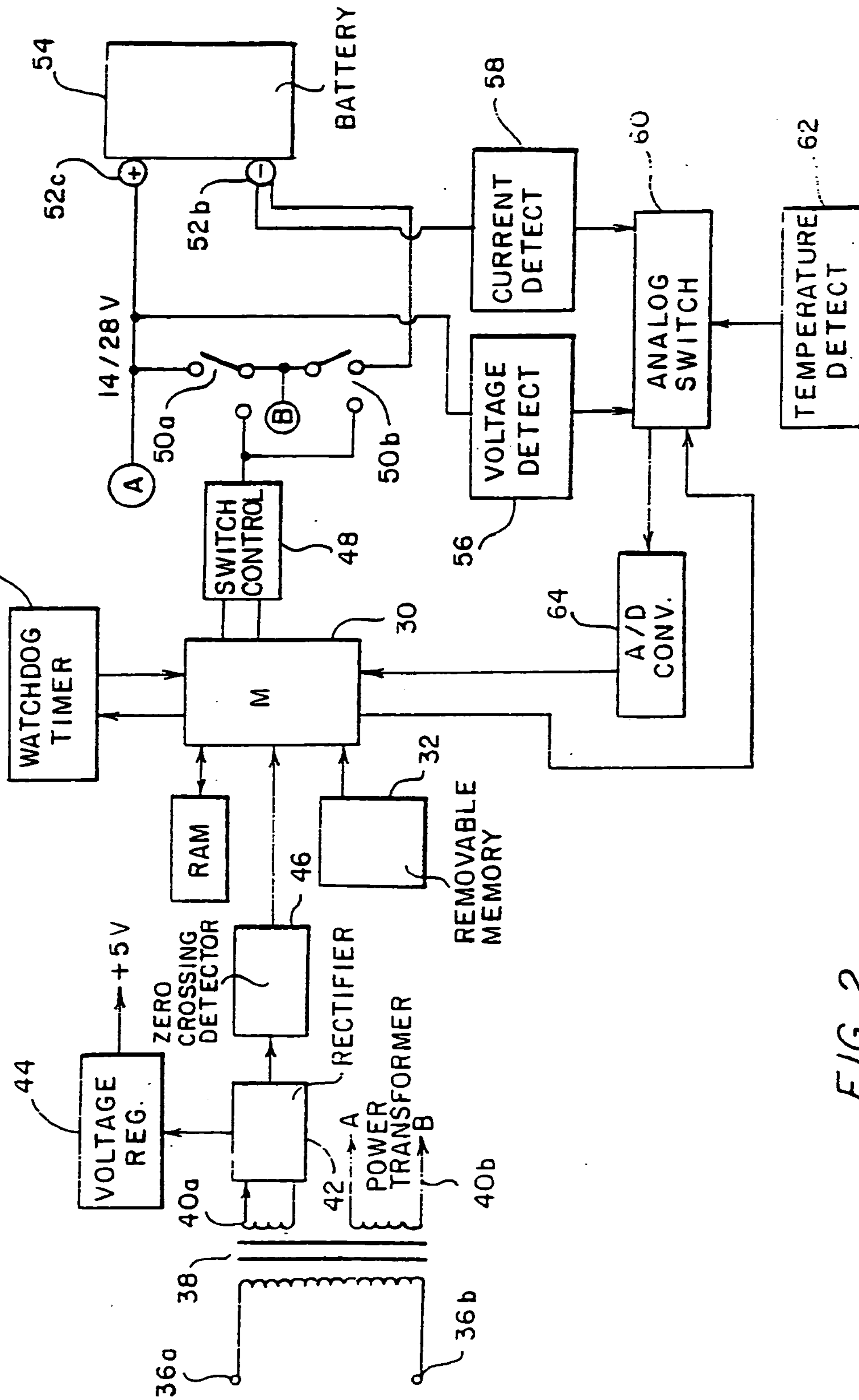
BATTERY
54
52c
52b
58
CURRENT DETECT
60
ANALOG SWITCH
62
TEMPERATURE DETECT
14/28 V
VOLTAGE DETECT
56
50a
50b
A
B
SWITCH CONTROL
48
34
WATCHDOG TIMER
M
30
64
A/D CONV.
RAM
32
REMOVABLE MEMORY
46
ZERO CROSSING DETECTOR
+5V
44
VOLTAGE REG.
RECTIFIER
POWER TRANSFORMER
42
40a
40b
38
36a
36b

FIG. 2

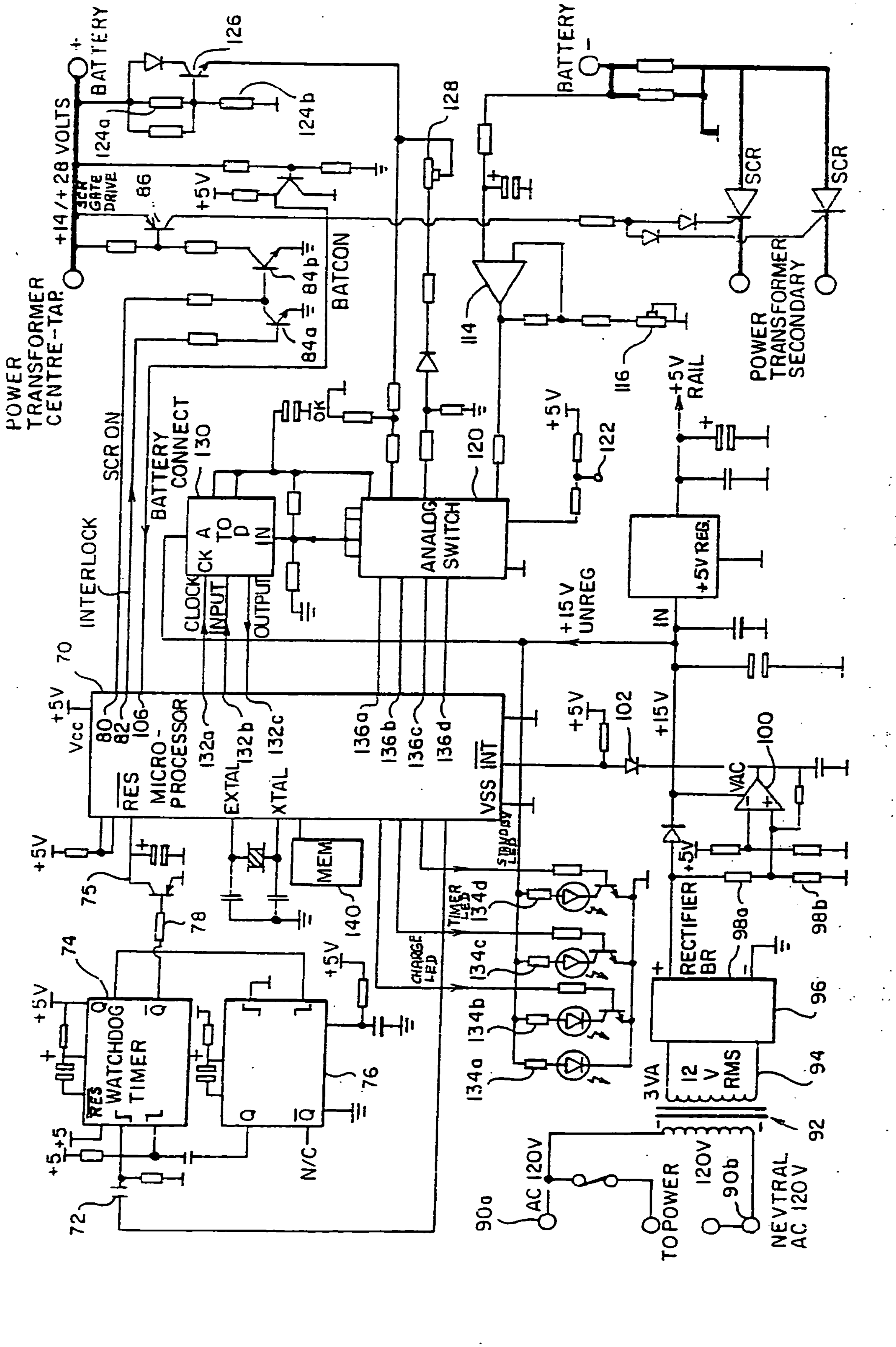
BATTERY +
BATTERY −
+14/+28 VOLTS
POWER TRANSFORMER CENTRE-TAP
SCR GATE DRIVE
BATCON
SCR ON
INTERLOCK
BATTERY CONNECT
A TO D
CK
IN
CLOCK
INPUT
OUTPUT
OK
ANALOG SWITCH
+5V REG.
+5V RAIL
+15 V UNREG
+15V
IN
SCR
POWER TRANSFORMER SECONDARY
MICRO-PROCESSOR
RES
Vcc
EXTAL
XTAL
VSS
INT
MEM
WATCHDOG TIMER
RES
N/C
STANDBY LED
TIMER LED
CHARGE LED
VAC
RECTIFIER BR
12 V RMS
3VA
AC 120V
TO POWER 120V
NEUTRAL AC 120V
+5V
70
72
74
75
76
78
80
82
84a
84b
86
90a
90b
92
94
96
98a
98b
100
102
106
114
116
120
122
124a
124b
126
128
130
132a
132b
132c
134a
134b
134c
134d
136a
136b
136c
136d
140

FIG. 3

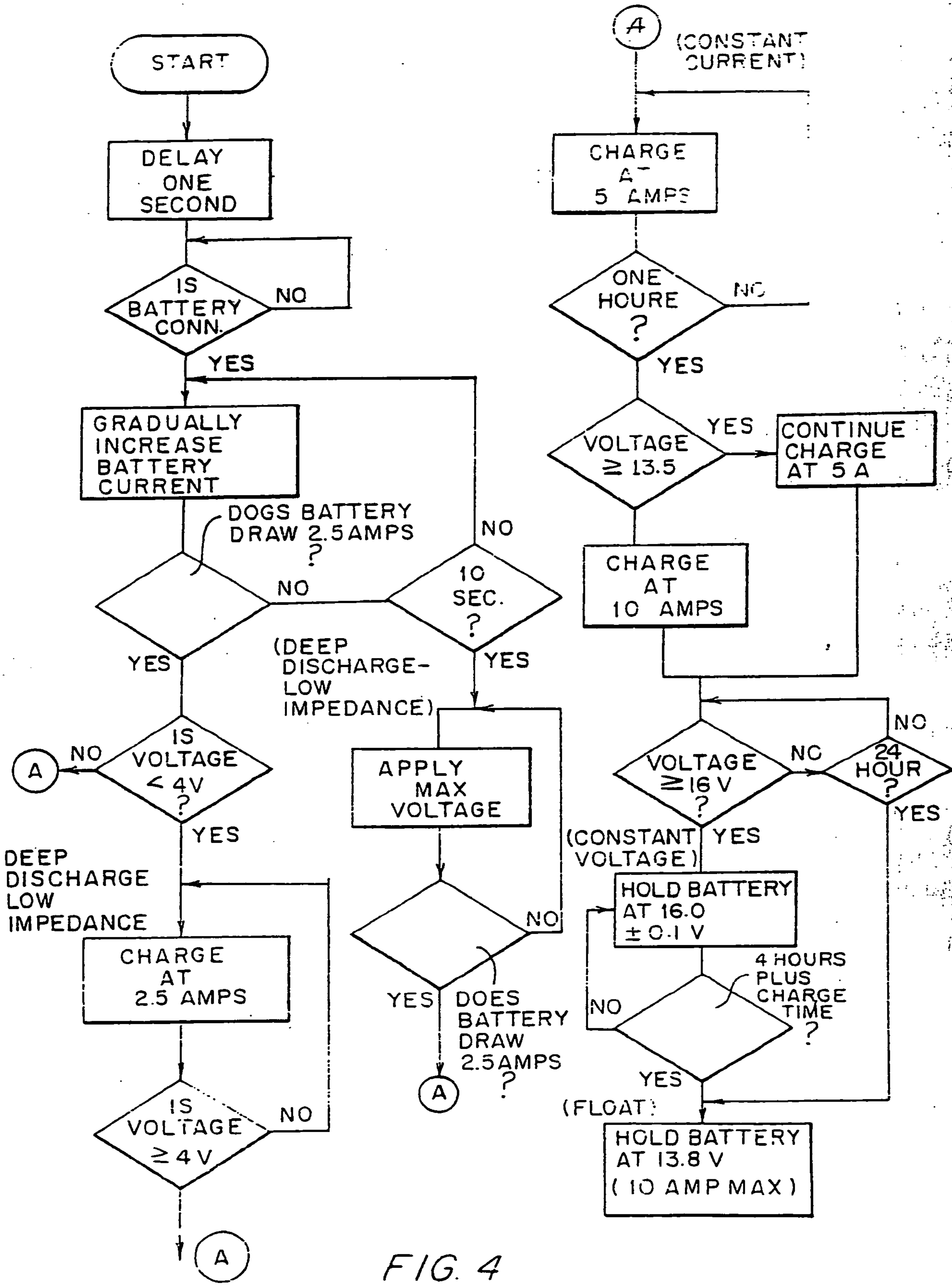
START
DELAY ONE SECOND
IS BATTERY CONN.
NO
YES
GRADUALLY INCREASE BATTERY CURRENT
DOGS BATTERY DRAW 2.5AMPS ?
NO
YES
10 SEC. ?
NO
YES
(DEEP DISCHARGE-LOW IMPEDANCE)
IS VOLTAGE < 4V ?
NO
A
YES
DEEP DISCHARGE LOW IMPEDANCE
CHARGE AT 2.5 AMPS
IS VOLTAGE ≥ 4 V
NO
A
APPLY MAX VOLTAGE
NO
YES
DOES BATTERY DRAW 2.5AMPS ?
A
A
(CONSTANT CURRENT)
CHARGE AT 5 AMPS
ONE HOURE ?
NO
YES
VOLTAGE ≥ 13.5
YES
CONTINUE CHARGE AT 5 A
CHARGE AT 10 AMPS
VOLTAGE ≥ 16 V ?
NO
24 HOUR ?
NO
YES
(CONSTANT VOLTAGE)
YES
HOLD BATTERY AT 16.0 ± 0.1 V
4 HOURS PLUS CHARGE TIME ?
NO
YES
(FLOAT)
HOLD BATTERY AT 13.8 V (10 AMP MAX)

FIG. 4

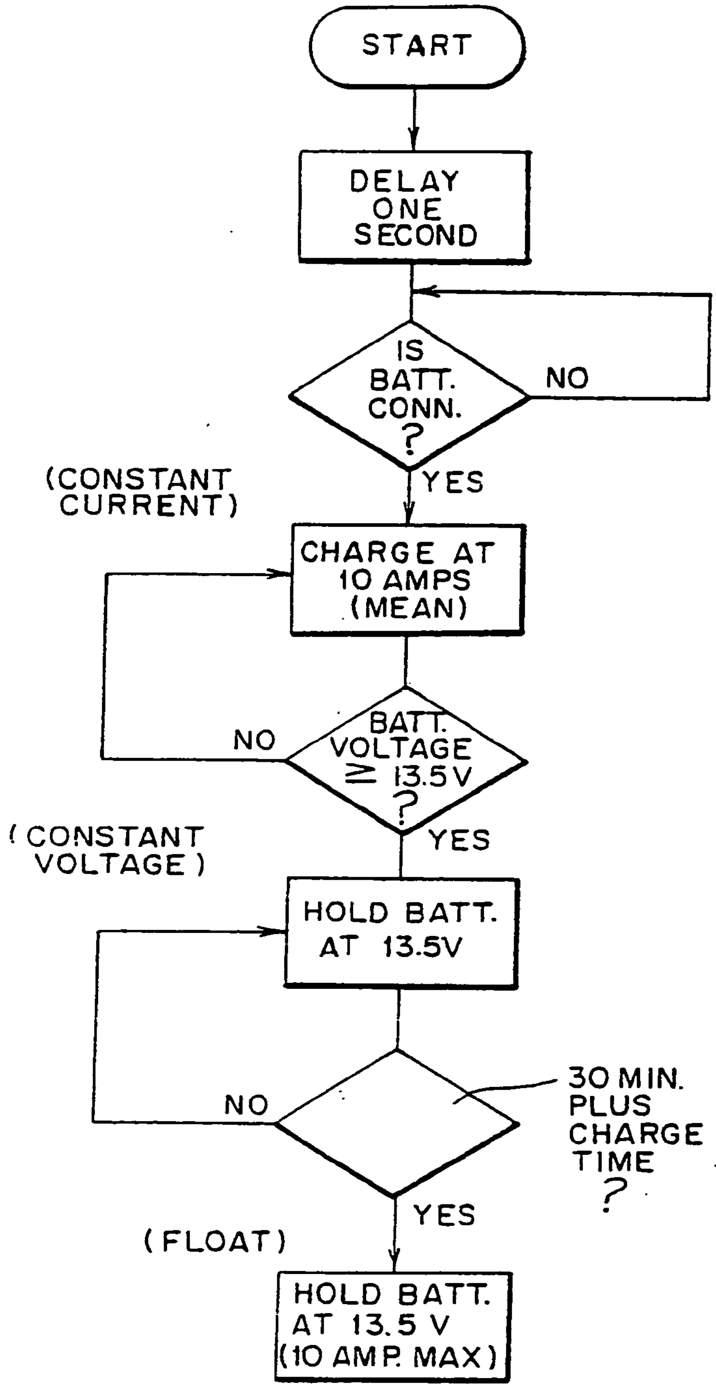
START
DELAY ONE SECOND
IS BATT. CONN. ?
NO
YES
(CONSTANT CURRENT)
CHARGE AT 10 AMPS (MEAN)
BATT. VOLTAGE ≥ 13.5V ?
NO
YES
(CONSTANT VOLTAGE)
HOLD BATT. AT 13.5V
30 MIN. PLUS CHARGE TIME ?
NO
YES
(FLOAT)
HOLD BATT. AT 13.5 V (10 AMP. MAX)

FIG. 5

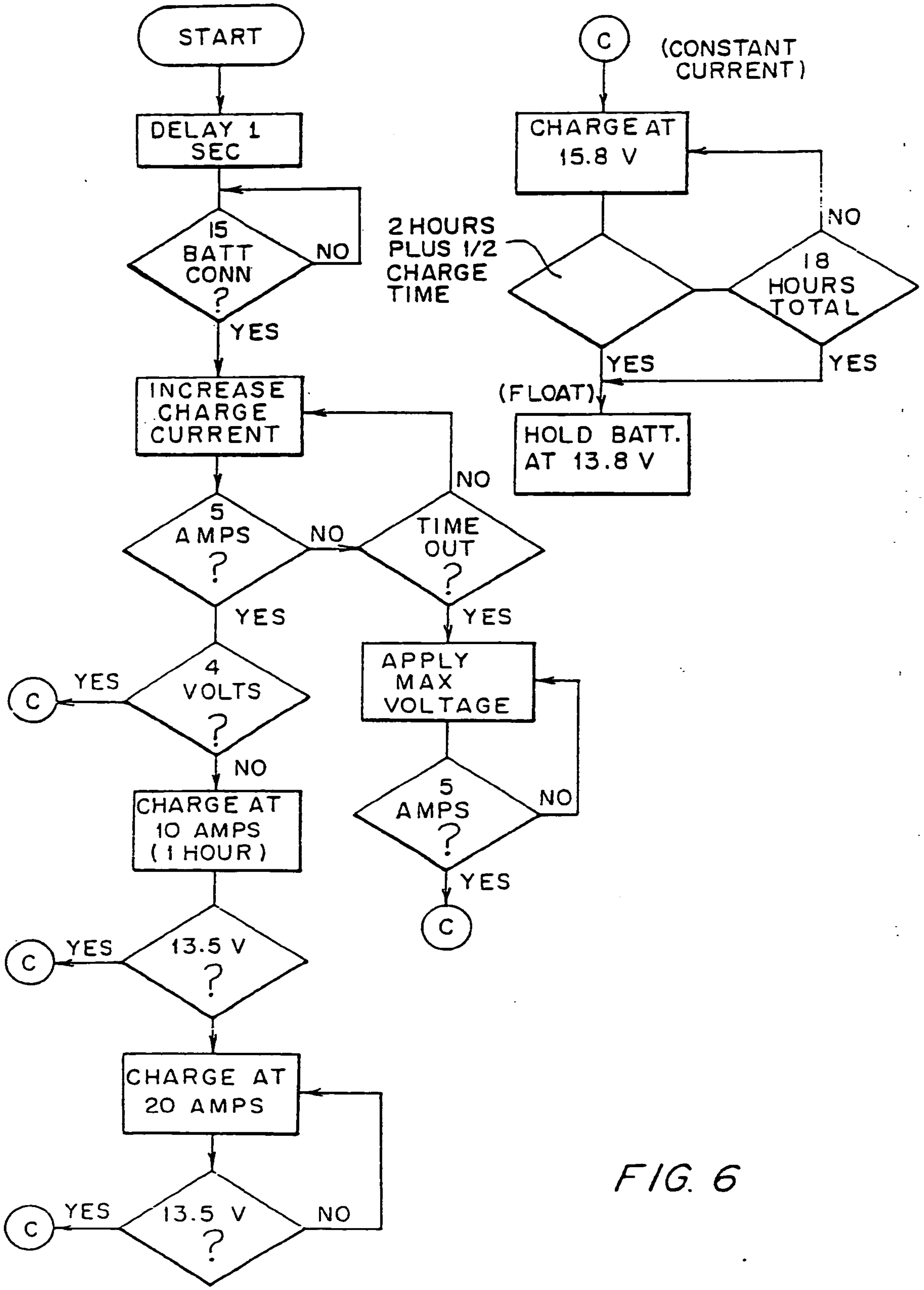
START
DELAY 1 SEC
15 BATT CONN ?
NO
YES
INCREASE CHARGE CURRENT
5 AMPS ?
NO
YES
TIME OUT ?
NO
YES
APPLY MAX VOLTAGE
5 AMPS ?
NO
YES
C
4 VOLTS ?
YES
C
NO
CHARGE AT 10 AMPS (1 HOUR)
13.5 V ?
YES
C
CHARGE AT 20 AMPS
13.5 V ?
YES
C
NO
C
(CONSTANT CURRENT)
CHARGE AT 15.8 V
2 HOURS PLUS 1/2 CHARGE TIME
18 HOURS TOTAL
NO
YES
YES
(FLOAT)
HOLD BATT. AT 13.8 V

FIG. 6